PAIRING RELATIONSHIPS AMONG FELDSPATHIC LUNAR METEORITES FROM MILLER RANGE, ANTARCTICA.
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Introduction: The Miller Range ice fields have been amongst the most prolific for lunar meteorites that ANSMET has searched [1-3]. Six different stones have been recovered during the 2005, 2007, and 2009 field seasons: MIL 05035 (142 g), MIL 07006 (1.4 g), MIL 090034 (196 g), MIL 090036 (245 g), MIL 090070 (137 g), and MIL 090075 (144 g). Of these, the five stones collected during the 2007 and 2009 seasons are feldspathic breccias. Previous work on the Miller Range feldspathic lunar meteorites (FLMs) has suggested that they are not all paired with each other [4-5]. Here we examine the pairing relationships among the Miller Range FLMs using petrography in concert with trace- and major-element compositions.

Methods: Trace-element compositions were determined by instrumental neutron activation analysis (INAA) of 20-35 mg subsamples of a single chip of MIL 07006 and three chips of each of the MIL 09 stones. Major-element compositions were determined by electron probe microanalysis (EPMA) of fused beads (FB) prepared from representative INAA subsamples of

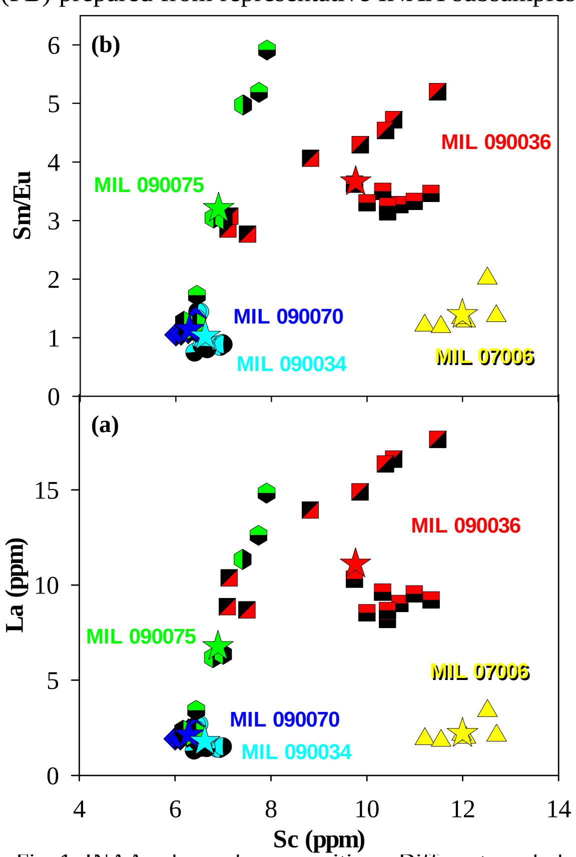

Fig. 1: INAA subsample compositions. Different symbols in each color represent different chips. Stars represent mass weighted mean compositions.

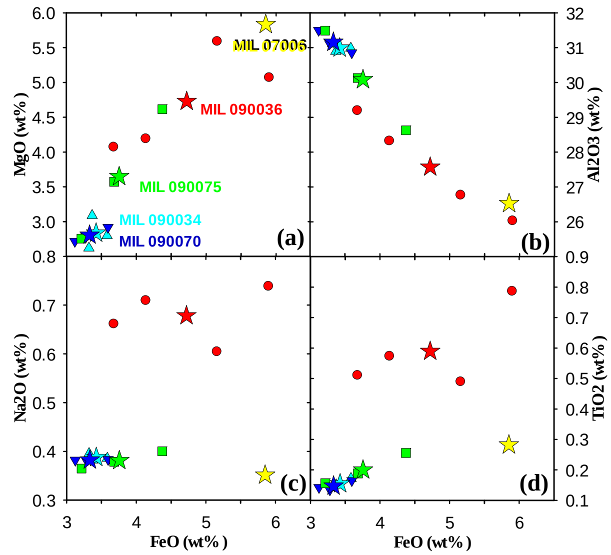

Fig. 2: FB-EMPA compositions of MIL subsamples. Stars represent mass weighted mean compositions.

each stone. The petrography of each stone was determined using back-scattered electron images, elemental x-ray maps, and quantitative EMPA of minerals. For more information on analytical techniques see [6-7].

Geochemistry: Subsamples of MIL 090034 and MIL 090070 have a restricted compositional range, both within a single chip and among different chips (Figs. 1,2). Both are highly feldspathic (~3.3 wt% FeO) and KREEP-poor (0.3 ppm Th). MIL 090036 is considerably more mafic (5.0 wt% FeO) and KREEPy (1.7 ppm Th) and shows a large compositional range, with no overlap in compositions of subsamples of the different chips. MIL 090036 is enriched in TiO_2 and the "plagiophile" elements (Na, Sr, Eu) relative to the other MIL 09 stones. MIL 090075 is intermediate to the other MIL 09 stones in FeO concentration (3.7 wt%) and Th concentration (1.1 ppm), and also shows a large compositional range. MIL 090075 does not have enrichments in TiO_2 and the plagiophile elements, however. Finally, MIL 07006 is the most mafic of the MIL FLMs (5.5 wt% FeO) and also has low concentrations of KREEPy (0.4 ppm Th) and plagiophile elements, as well as TiO_2.

Petrography: All four MIL 09 stones are very immature regolith breccias. Each contains abundant large clasts of impact-melt breccia set in a glassy matrix which also contains abundant fine-grained mineral and lithic clasts. The edges of the mineral and lithic clasts are "blurry", tending to blend into the glassy matrix. The most abundant clast type in the MIL 090034, 090070, and 090075 stones are feldspathic impact-melt

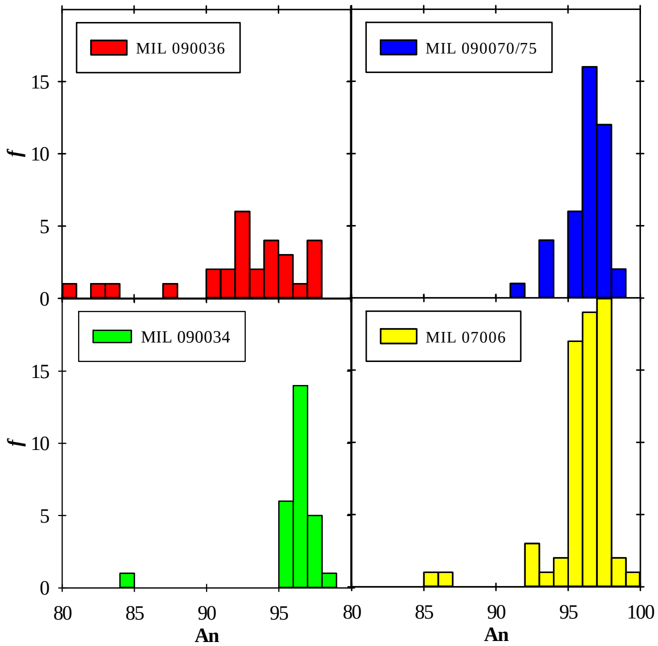

Fig. 3: Plagioclase histograms for FLMs from Miller Range.

breccias with highly calcic plagioclase (An_{95-97}; Fig. 3), moderately magnesian pyroxene ($Wo_{10-25}En_{45-57}$; Fig. 4) and olivine (Fo_{55-60}). The most abundant lithic clasts in the MIL 090036 stone are also impact-melt breccias; however, they are more mafic and contain more sodic plagioclase (An_{90-94}) and magnesian pyroxene ($Wo_{8-18}En_{50-70}$) and olivine (Fo_{60-65}) than the IMB clasts in the other MIL 09 stones. Other lithic clasts in the MIL 09 stones are typically small granulites, impact-melt breccias, and norites. Again, the clasts in MIL 090036 typically have more sodic plagioclase (An_{90-95}) and slightly more magnesian pyroxene (En_{53-74}) and olivine (Fo_{60-75}) compositions than plagioclase (An_{94-97}), pyroxene (En_{40-67}), and olivine (Fo_{60-70}) in the comparable clasts in the other three MIL 09 stones. Shock-melt veins are observed in each of the MIL 09 stones; their bulk compositions are similar to the bulk composition of the stones based on FB-EMPA analysis.

The MIL 07 stone is also an immature regolith breccia containing abundant mineral and lithic clasts in a glassy matrix. The glassy matrix in MIL 07006 is slightly vesicular and clasts in MIL 07006 have distinct boundaries with the matrix glass. MIL 07006 lacks large clasts akin to the impact-melt breccia clasts in the MIL 09 stones. Instead, its lithic clast load contains chiefly of abundant small granulite and impact-melt breccias clasts (both crystalline and glassy-matrix varieties). Plagioclase compositions in MIL 07006 are largely invariant, most falling in the An_{94-98} range. Pyroxene and olivine compositions in the lithic clasts (En_{48-78}; Fo_{63-80}) are considerably more magnesian than pyroxene and olivine compositions in the mineral clasts (En_{10-52}; Fo_{60-61}). This difference is likely due to mineral clasts from with a basaltic provenance. Previous investigators described lithic basalt clasts [8,9], which were not seen in our section.

Discussion: On the basis of similarities in bulk composition, macroscopic description [3], and petrography it is clear that MIL 090034, MIL 090070, and MIL 090075 are paired. Minor differences in the bulk composition of MIL 090075 are likely due to sampling issues related to our sample size relative to the course-grained nature of the clasts (up to 1 cm) in these three stones. MIL 090036 does not appear to be paired with the other MIL 09 stones, however. Although subsamples of MIL 090075 appear to bridge the compositional gap between MIL 090036 and MIL 090034/70 on some plots (Figs. 1a; 2a,b), there is a clear dichotomy in composition on plots involving plagiophile elements and TiO_2 (Figs. 1b; 2b,c). Moreover, the average composition of mafic silicates are more magnesian and the plagioclase is more sodic for MIL 090036 than in the other MIL 09 stones (Figs. 3,4). A recently discovered FLM, NWA 7022, is compositionally similar to MIL 090036, however [10]. MIL 07006 is dissimilar in petrography and bulk composition from all the MIL 09 stones and is not paired with any of them. It is most similar (but not paired) to PCA 02007 and Y-791197 [11].

References: [1] McBride K. et al. (2006) *Ant. Met. News.*, **29**(2). [2] McBride K. et al. (2008) *Ant. Met. News.*, **31**(2). [3] Corrigan C. et al. (2010) *Ant. Met. News.*, **33**(2). [4] Korotev R.L. et al. (2011) *LPSC* **42**, #1999. [5] Liu Y. et al. (2011) *LPSC* **42**, #1261. [6] Korotev R.L. et al. (2009) *MAPS* **44**, 1287–1322. [7] Korotev R.L. et al. (2006) *GCA* **70**, 5935–56. [8] Joy K.H. et al. (2010) *LPSC* **41**, #1793. [9] Liu Y. et al. (2009) *LPSC* **41**, #2105. [10] Kuehner S. M. et al., NWA 7022, this conf. [11] Korotev R.L. et al. (2009) *LPSC* **40**, #1137. **Acknowledgements:** We thank ANSMET and JSC for the meteorites. This work was supported by NASA grants NNG04GG10G and NNX11AB26G (RLK).

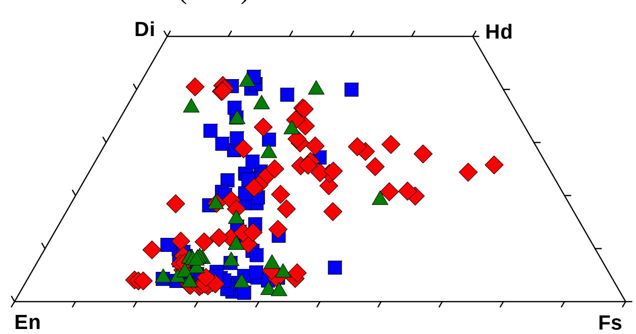

Fig. 4: MIL 07006 (red), MIL 090036 (green), and MIL 090034/70/75 (blue) pyroxenes compositions.